



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

SPECULATIONS REGARDING THE GENESIS OF THE DIAMOND. II

ORVILLE A. DERBY

Geological and Mineralogical Service of Brazil, Rio de Janeiro

Since writing the paper with the above title that appeared in the October-November, 1911, number of this journal Fersmann and Goldsmidt's monograph¹ on the crystalline form of the diamond has come to hand and its perusal has suggested some additional observations on the subject.

From the genetic point of view the most important deduction drawn by the authors from their epoch-making studies is stated on p. vii of the Introduction in the following terms: *All the diamond crystals known to us have been formed suspended in a molten mother-liquid (magma)*. Since the present paper is of a speculative nature, I venture to restate, provisionally, this law as follows: *Diamond crystals have been formed suspended in a medium sufficiently mobile, or susceptible to solution (replacement), to permit their free, all-round development*. The most essential difference between the two forms of statement is the elimination in the latter of preconceived ideas regarding the physical condition of the enclosing rock at the moment of the crystallization of the mineral.

Another important deduction from the studies of Fersmann and Goldsmidt is the extreme delicacy of the saturation point for carbon of the solution from which the material of the diamond crystals was derived, from which it resulted that growth (due to supersaturation) and reabsorption (due to incomplete saturation) alternated in the formation period of the great majority of the individuals in a way that thus far has not been recorded as so nearly universal for any other mineral species.²

¹ *Der Diamant*, Heidelberg, 1911.

² My examination of numerous heavy residues containing zircon and monazite from granites and gneisses shows that these minerals are more frequently rounded from reabsorption than sharp-cut. The same remark can be made regarding the magnetite and ilmenite grains that occur in so many eruptive rocks.

In a recent article Irving¹ has discussed the formation of *complete* crystals in rock masses. Those that are of primary origin in igneous rocks were, naturally, formed in a magma that was mobile through fusion, while those of secondary origin are attributed to replacement. In sedimentary or other rocks already consolidated, space for such crystals could, according to Irving, only be gained through displacement of granules of the enclosing rock by virtue of the force of crystalline growth, or through the removal by solution of such molecules of the rock as occupied the space to be taken up by the crystal in process of formation.

The minerals mentioned by Irving as having had their lodging-place prepared by solution represent sulphides (pyrite, galena), carbonates (siderite), fluorides (fluorite), and boron-bearing silicates (tourmaline), from which it may be inferred that the requisite solvent power is an attribute of the so-called mineralizing agents: sulphur, carbon in some one or more of its gaseous forms, fluorine, and boron.

No precise statement regarding the character of the molds left by the dislodgement of diamond crystals from their parent-rock, kimberlite, is at hand, but judging from the current hypotheses (formed in place or floated up from some pre-existent rock), these should be as sharp-cut and perfect as those of the above-mentioned replacement minerals. Such perfect molding occurs with minerals formed in mobile (molten) media, and in the case of the diamond no other hypothesis seems to have ever been considered, but with our present scanty knowledge of the obscure subject of the genesis of that mineral the hypothesis that it may be due to replacement cannot be lightly put aside.

The studies of Beck² and Bonney³ on the so-called eclogite nodules from the Newlands mine offer some support to this last hypothesis. A number of these were examined by both authors, but apparently only a single diamond-bearing one was ever found,

¹ "Replacement Ore Bodies and the Criteria for Their Recognition," *Economic Geology*, October-November, 1911.

² "Untersuchungen über einige südafrikanische Diamantenlagerstätten," *Zeit. d. deutsch. geol. Gesell.*, 1907, pp. 290 f.

³ "The Parent-Rock of the Diamond in South Africa," *Proc. Roy. Soc.*, LXV (1899), p. 229.

or at least brought to Europe. They consist essentially of diopside and garnet, the former mineral predominating in the sterile nodules and the latter in the diamond-bearing one. The small flake studied by Beck had the volume of a cube of 7-8 centimeters length of side and showed five diamonds on the fractured faces. Six more were obtained by crushing some small detached fragments, from which it was estimated that the whole flake contained some dozens of diamond crystals, and the original nodule from which it was broken (said to have been of about the size of a child's head) some hundreds. The diamonds were embedded in the diopside¹ or between this mineral and the garnet. The granules of garnet were covered with a thin dark crust similar in appearance to the well-known kelyphite rim found on this mineral in many other rocks but apparently of a somewhat different character. This crust was not reported on the garnet of the much more abundant sterile nodules, and if it occurs at all in them, it is apparently localized in certain spots that were not critically examined.

The accompanying figure reproduced from Bonney shows the relation of a diamond crystal to a neighboring granule of garnet covered with its characteristic crust, which is said to extend also into cracks in the garnet.

If, instead of to the diamond, this figure referred to any one of the above-mentioned replacement minerals, the following interpretation of the phenomena registered in it would probably be accepted by most, if not by all, mineralogists who have occupied themselves with the study of the genesis of minerals.



Garnet and diamond (diagrammatic, nearly twice natural size): (1) Diamond, (2) garnet, (3) kelyphitic rim.

A dyke, or pipe, of kimberlite containing nodules (segregations) of diopside and garnet was subjected to pneumatolitic action that introduced water and carbonic acid into the rock, producing the serpentinization of a considerable part of it accompanied by the formation of calcite. Some of the included nodules (the more brittle ones containing more garnet than diopside would have been

¹ See figures in *Zeit. f. prak. Geol.*, May, 1898, p. 164.

most affected by the previous fracturing that the rock had suffered) were affected by this action, as is evidenced by the production of a crust of secondary minerals on the surface and in the cracks of the garnet and produced at its expense.¹ At a certain point on the surface of the granule here considered that was being attacked, certain ingredients contained to the point of supersaturation in the corroding solution commenced to separate out in a crystalline form, substituting the crust which at that point was being redissolved on its outer surface while its formation continued on the inner one. In front and around the growing crystal the solvent action of the solution on the garnet and the consequent formation of the crust became more active than elsewhere, thus lowering the original surface at that point and producing the bay-like indentation in which the crystal rests.

All the hypotheses thus far presented for the genesis of the diamond are difficultly reconcilable with the known geological conditions of its occurrence as summarized, so far as regards those that are most essential, in my previous paper. Friedländer² has demonstrated experimentally that the diamond can be produced artificially by introducing solid carbon into fused olivine without artificial pressure and at a temperature (that afforded by the oxyhydrogen blowpipe) considerably below that thought indispensable by previous experimenters.³ We can therefore in our speculations on the subject eliminate altogether the element of pressure and, until the contrary is proven experimentally, admit hypothetically a still further extension downward of the range of temperature which, under varying conditions in other respects, will permit the crystallization of carbon in the form of diamond.

In speculating on the genesis of the diamond we can therefore put aside, at least hypothetically, the formidable ancient bugbear

¹ In this case the dissolved material was redeposited *in situ*. If we imagine that the material that, as may be presumed, was concurrently dissolved from the diopside was carried away (and perhaps with it a certain portion of redissolved garnet crust), a plausible explanation is found for the much-discussed rounded form of these nodules.

² "Herstellung von Diamanten in Silikaten entsprechend dem natürlichen Vorkommen im Kaplande," *Verh. d. Vereins z. Beförderung des Gewerbflusses*, February, 1898, p. 45.

³ A repetition of these experiments with other minerals, especially diopside and garnet, might give a very desirable addition to our knowledge of the subject.

of extraordinary pressure and heat, and thus nothing of serious importance stands in the way of a thoughtful consideration of the hypothesis here presented that the diamond is a secondary mineral crystallized out of some carbon-bearing solution that was capable of dissolving the rock (or some parts of it) in which it occurs and thus of opening space for it. This hypothesis can be easily reconciled with the geological conditions in which the diamond occurs in its parent-rock, in so far at least as these conditions are known at present. These, as set forth in my previous paper, combined with the present one, are as follows:

1. The diamond occurs in the form of isolated complete crystals closely enclosed in a rock of eruptive origin occurring in dykes and pipes and having the readily alterable minerals olivine and pyroxene as its leading essential constituents.

2. This rock, wherever diamonds have been found in it, shows evidence of having been fractured after its consolidation to such an extent as to permit a sufficiently free circulation of subterranean solutions to produce a very advanced stage of alteration in all its olivine-bearing portions, so that the only portions that remained perfectly fresh are certain unfractured pyroxene-garnet segregations free from olivine.

3. The circulating solutions introduced water (locked up in the serpentine and other secondary minerals) and carbon (locked up in the calcite) both of which were lacking in the original rock.

4. The circulating solutions attacked the garnet of the enclosed pyroxene-garnet segregations wherever these were sufficiently fractured to permit it, producing an alteration crust of secondary minerals. Unfractured segregations would naturally be attacked only on their surfaces adjacent to the more fractured and thus more permeable olivine-bearing portions of the rock, and thus their (presumably) rounded original form would be accentuated through corrosion, giving them the aspect of water-worn pebbles.

5. After (or concurrently with) the alteration of the garnet, carbon crystallized in the form of diamond adjacent to the secondary crust formed on the former mineral, and also, as Beck demonstrated in his study of the diamond-bearing nodule from the Newlands mine, in the form of graphite.

The conditions above enumerated are, in their most essential particulars, strikingly similar to those under which the mineralization, with auriferous sulphides, took place in the Passagem lode, as set forth in my recent paper in the *American Journal of Science* (September, 1911), in which, however, no mention was made of two circumstances of certain importance for the present discussion. These are: (1) large and ideally perfect crystals of arsenopyrite occur in certain portions of the hanging wall under conditions corresponding exactly to the cases of replacement cited by Irving for the sulphides pyrite and galena,¹ and (2) slick-sided planes at or near the upper side of the lode are abundantly coated with graphite which is at times segregated in lumps of the size of the fist.

Whether in this case the carbon separated out from the tourmaline-forming or the sulphide-forming solution could not be determined and is immaterial in the present discussion. Whatever its carrier may have been, it is here certain that carbon was deposited in one of its two solid mineral forms from a solution capable of dissolving portions of the rock in which it circulated, and thus of opening space for the deposit from some of the other of its mineral contents, in the form of replacement minerals such as tourmaline and arsenopyrite.

¹ The containing rock consists of a finely granular mixture of quartz, magnetic pyrite, and calcite. Where replaced, the two latter minerals disappeared while the quartz granules remained locked up in the crystals of arsenopyrite.